Influence of the Major Drainages to the Mississippi River and Implications for System Level Management

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The Mississippi River

- ~ 3,770 km from source at Lake Itasca, MN to terminus of Southwest Pass in the Gulf of Mexico
- Heavily modified by permanent engineering structures such as: dams, locks, levees, channel revetments and wing dams; also subject to channel dredging

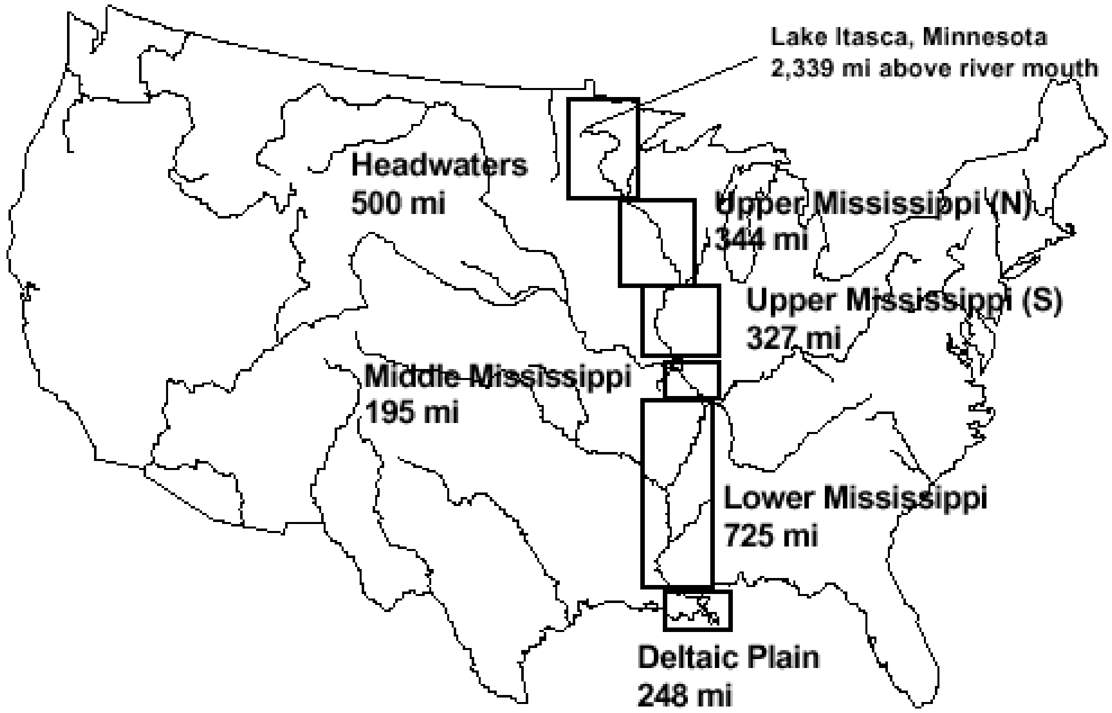


Figure 1. Mississippi River Segments

Table 1. Mississippi River Floodplain

River Segment	*Approximate Floodplain Acres in 1,000s*	*Percent of Floodplain Behind Levees*
Headwaters	328	<0.01%
Upper Mississippi (N)	496	3%
Upper Mississippi (S)	1,006	53%
Middle Mississippi	663	82%
Lower Mississippi	25,000	93%
Deltaic Plain	3,000	96%
TOTALS	30,493	90%

The Mississippi River Basin (MRB)

- Drains all or part or 31 U.S. states and 2 Canadian provinces
- 3.2 million square kilometers
- 41 % of the Lower 48 states
- Over the last 200 years, most natural vegetation has been replaced by an intensely farmed landscape

The Mississippi River Basin (MRB)

- Divided into 6-7 major sub-basins (major watersheds)
  - Ohio, Missouri, Arkansas, Red, Upper and Lower Mississippi (Middle Mississippi)
- Sub-basins have diverse extent, geology, geography, climate, land use and water management
- This leads to disproportionate yields of water, sediment and nutrients into the main stem of the Mississippi

ALBERTA
SASKATCHEWAN
Milk
MONTANA
Missouri
NORTH DAKOTA
MINNESOTA
Yellowstone
Little Missouri
Billings
Grand
Tongue
Bighorn
James
Minnesota
Minneapolis
Mississippi
Wisconsin
Big Sioux
Wind
Cheyenne
SOUTH DAKOTA
Niobrara
Des Moines
Iowa
WISCONSIN
MICHIGAN
NEW YORK
North Platte
NEBRASKA
Missouri
Chicago
WYOMING
Loup
Omaha
Des Moines
Kankakee
Allegheny
PENNSYLVANIA
Platte
Lincoln
IOWA
South Platte
Illinois
Peoria
Wabash
OHIO
Pittsburgh
Republican
INDIANA
Scioto
Columbus
Springfield
Denver
Kansas City
Indianapolis
Monongahela
Kansas
Kaskaskia
Cincinnati
WEST VIRGINIA
Smoky Hill
Topeka
ILLINOIS
Ohio
Kanawha
St. Louis
Evansville
Lexington
Arkansas
Neosho
VIRGINIA
COLORADO
KANSAS
MISSOURI
Green
Kentucky
KENTUCKY
Holston
White
Black
New
OKLAHOMA
Tulsa
Cumberland
Canadian
NORTH CAROLINA
Oklahoma City
ARKANSAS
TENNESSEE
Tennessee
Memphis
Mississippi
NEW MEXICO
Red
SOUTH CAROLINA
Ouachita
Yazoo
ALABAMA
GEORGIA
MISSISSIPPI
TEXAS
Baton Rouge
Atchafalaya
LOUISIANA
New Orleans
About 2,000 miles (3,219 km) across

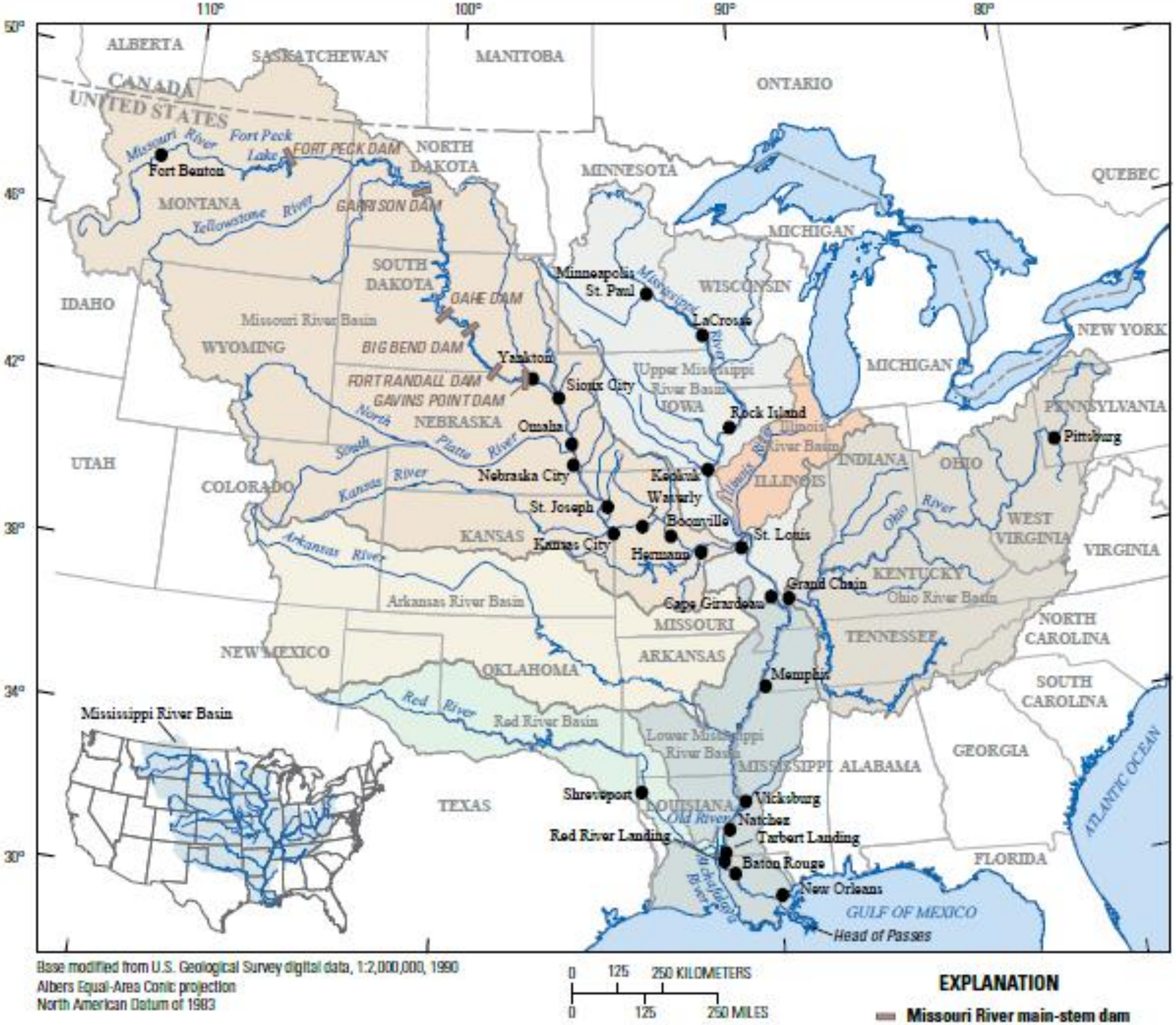
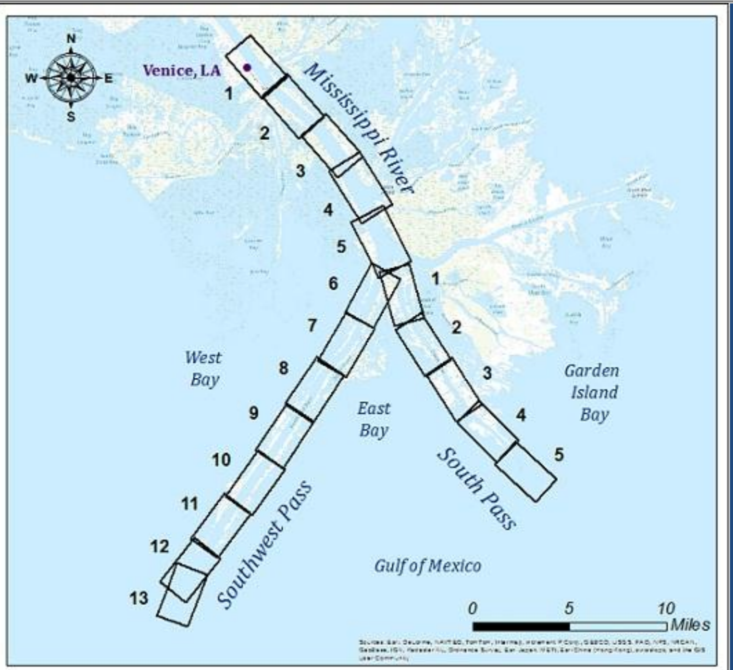


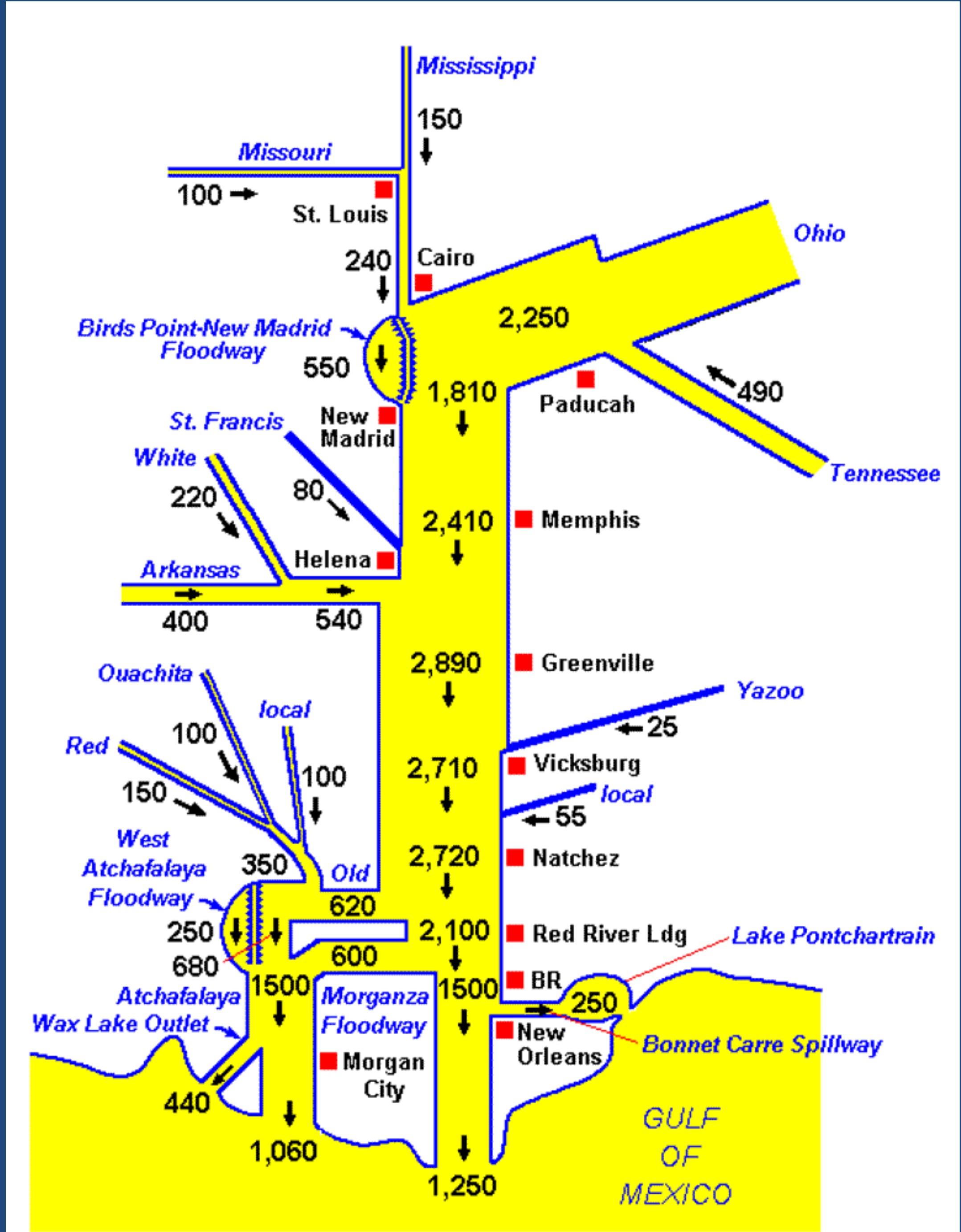
Figure 1. Mississippi River Basin, primary tributaries, large main-channel dams, and selected cities along main-stem channels.

MRB Management Priorities (in alphabetical order)

- **Flood prevention/ Flood control**
  - Dams, Levee System, Floodways/spillways
- **Navigation**
  - Maintain navigation channel depth and/or width by dredging and/or lock and dam operation, hard structures
- **Restoration**
  - Includes restoration of inland ecosystems along the entire Mississippi river and floodplain as well as <u>coastal restoration of the deltaic plain in Louisiana</u>


Old River Control
Fort Adams Reach
Smithland 1,2,3
Bayou Sara
Wilkerson Point
Baton Rouge, LA
Baton Rouge Front
Redeye
Sardine Point
Medora
Granada
Bayou Goula
Philadelphia Point
Alhambra
Smoke Bend
Fairview
Rich Bend
Belmont
New Orleans, LA
0
10
20
Miles
N
S
W
E


Venice, LA
Mississippi River
West Bay
East Bay
Garden Island Bay
South Pass
Southwest Pass
Gulf of Mexico
0
5
10
Miles
N
S
W
E
1
2
3
4
5
6
7
8
9
10
11
12
13


Mississippi
150
Missouri
100
St. Louis
240
Cairo
Ohio
2,250
Birds Point-New Madrid Floodway
550
1,810
Paducah
490
Tennessee
St. Francis
New Madrid
White
80
220
2,410
Memphis
Helena
Arkansas
400
540
2,890
Greenville
Ouachita
Yazoo
local
25
Red
100
100
2,710
Vicksburg
150
local
55
West Atchafalaya Floodway
350
Old
2,720
Natchez
620
250
2,100
Red River Ldg
Lake Pontchartrain
680
600
Atchafalaya
1500
Morganza Floodway
1500
BR
250
Wax Lake Outlet
New Orleans
Bonnet Carre Spillway
Morgan City
440
1,060
1,250
GULF OF MEXICO

Mississippi River Resource Based Coastal Restoration Projects

- Direct creation of wetland habitat through dedicated dredging and placement or beneficial use of dredged navigation channel material in open water/ broken marsh
- Diversions of freshwater for salinity control and/or nutrient introduction
- Diversions designed to capture considerable amounts of sediment and promote deltaic land building processes in interdistributary basins

Mississippi River Resource Based Coastal Restoration Projects

- In order to plan, implement and operate restoration projects in the most effective manner, particularly land building diversions, it is important to understand the dynamic nature of water, sediment and nutrient loading into the main stem from the sub-basins
- Total input, yield, timing, source sub-basin…

Three Main Fluxes

- **Water**
  - Liquid precipitation, snow melt
- **Sediment**
  - Fine grained "wash load" – clay and fine silt
  - Coarse grained "bed load" – coarse silt, sand and gravel
- **Nutrients**
  - C,N,P, Silicate

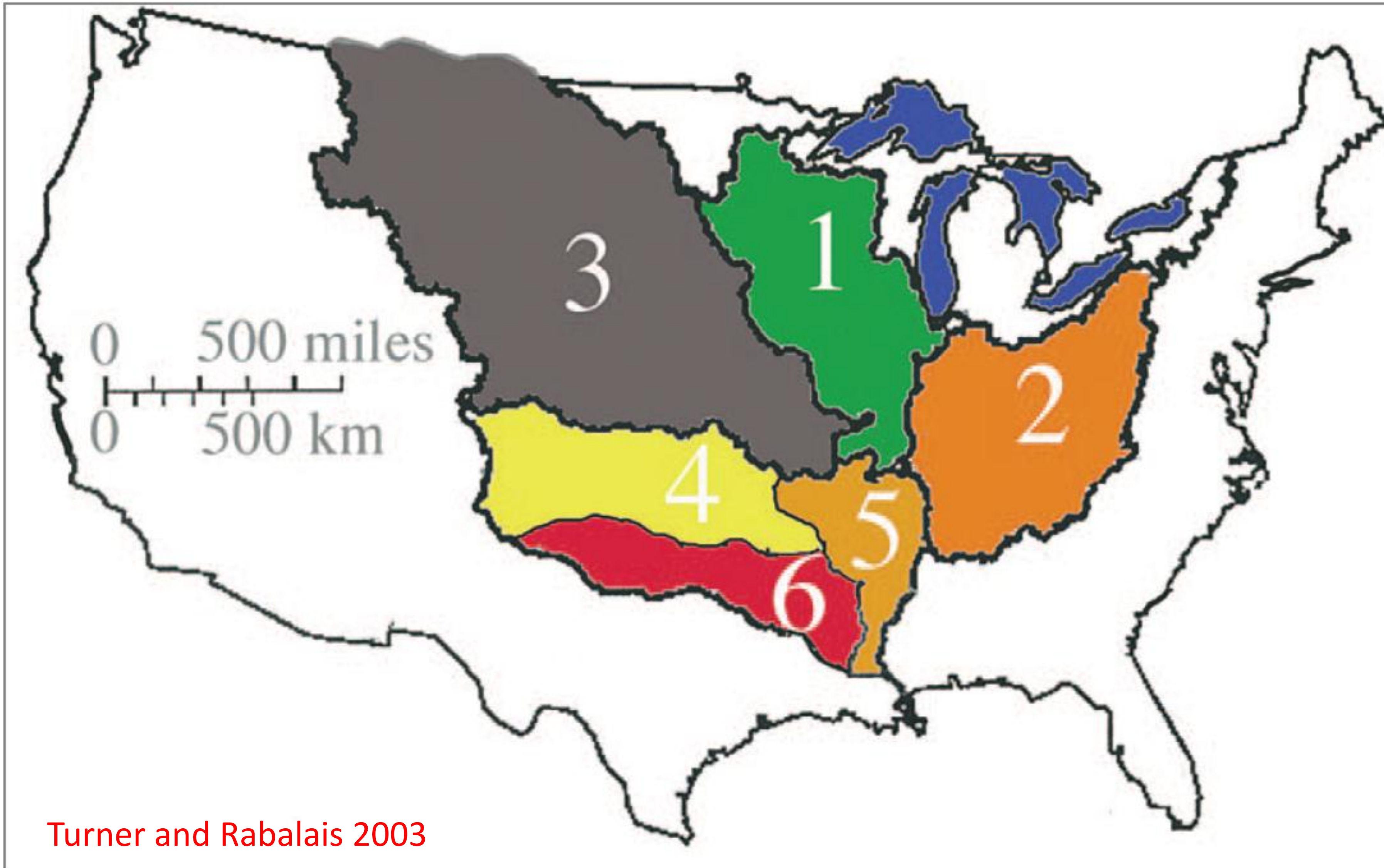
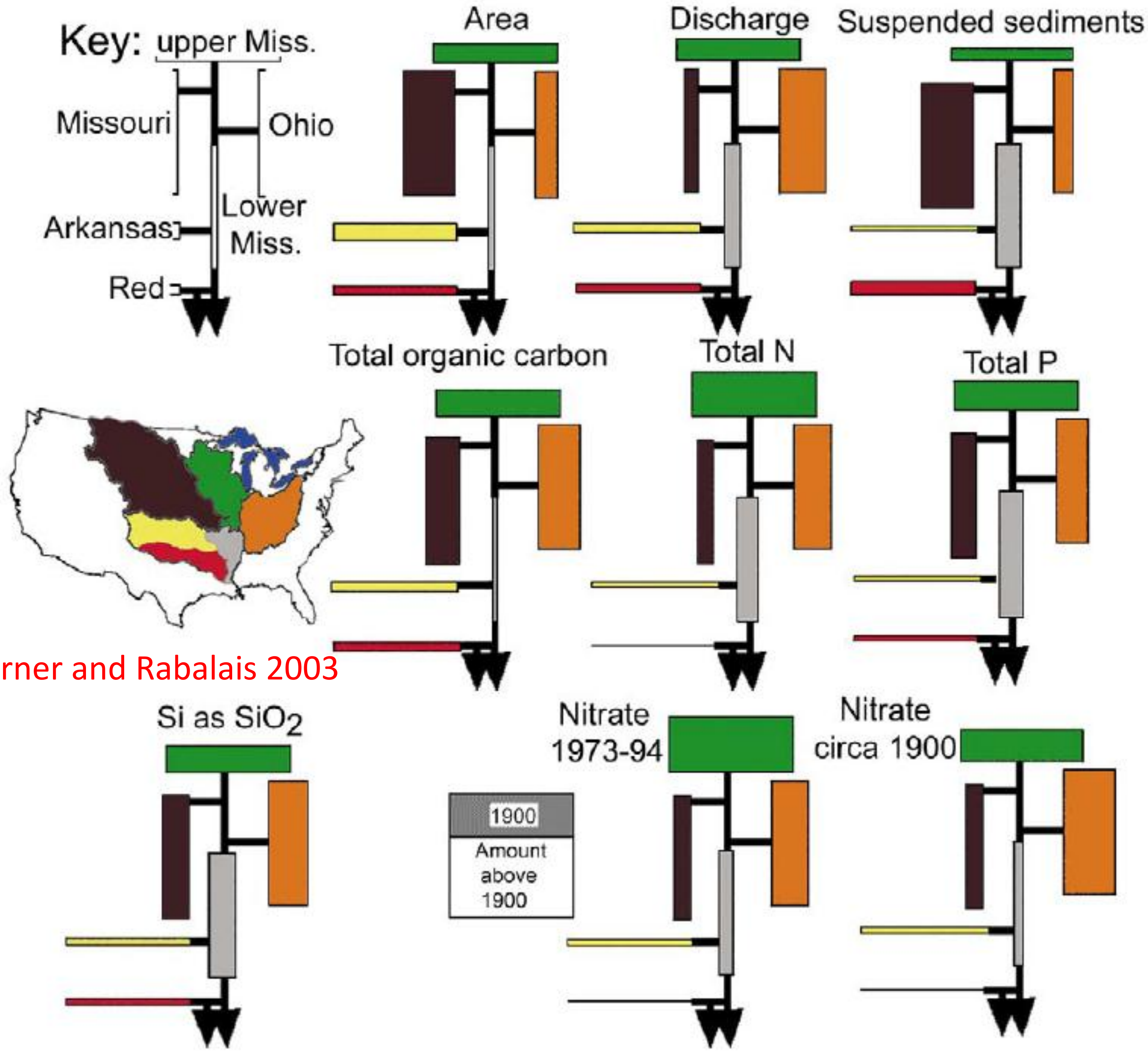


Figure 1. The Mississippi River Basin and the major watersheds discussed in this article. Key: 1, upper Mississippi River; 2, Ohio River; 3, Missouri River; 4, Arkansas River; 5, lower Mississippi River; 6, Red River. The total combined area is 41% of the contiguous states.

Water Flux

- The Ohio watershed alone contributes 40-50% of the total annual water flux, but only represents 16% of total area of MRB
- The Missouri watershed, largest of the sub-basins, covering 43% of the MRB, contributes only about 10-13% of the total annual water flux



Turner and Rabalais 2003

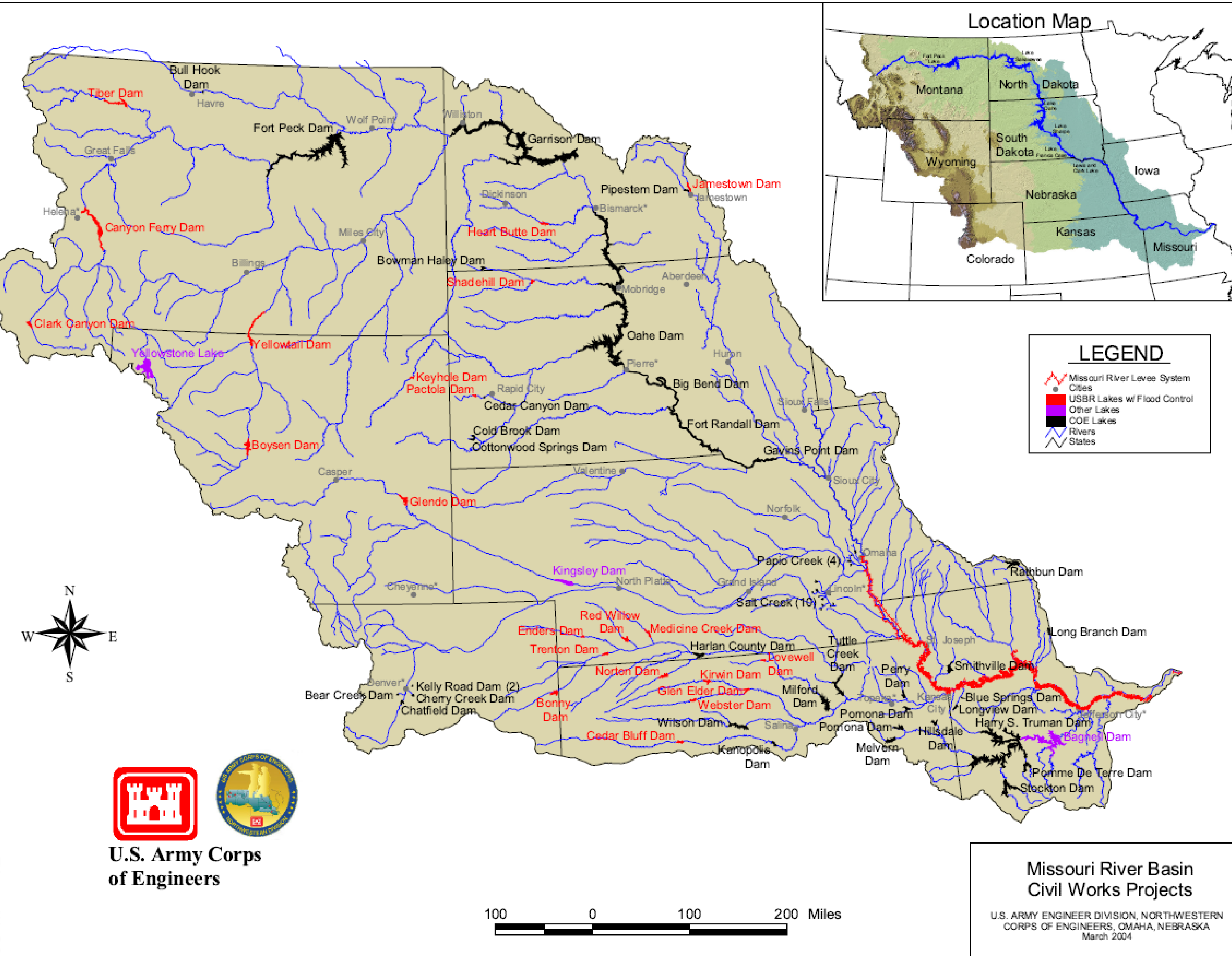
Water Control

- Dams are utilized throughout the MRB to stabilize, harness and regulate the discharge of rivers. They have also allowed for agricultural expansion into nutrient rich soils of bottomlands adjacent to rivers
- Thousands of single and multipurpose structures provide flow and stage regulation for navigation, flood control and protection, hydropower, water supply, irrigation, aquatic and terrestrial habitat, and recreation
- Although these structures are distributed throughout the MRB, the Missouri Basin is the most intensely modified, with upwards of 17,000 structures

Water Control
Missouri Basin

- Six large dams on the main stem of the Missouri have had the effect of lowering flood magnitude below the dam at high discharges and raising base flows at low discharge periods

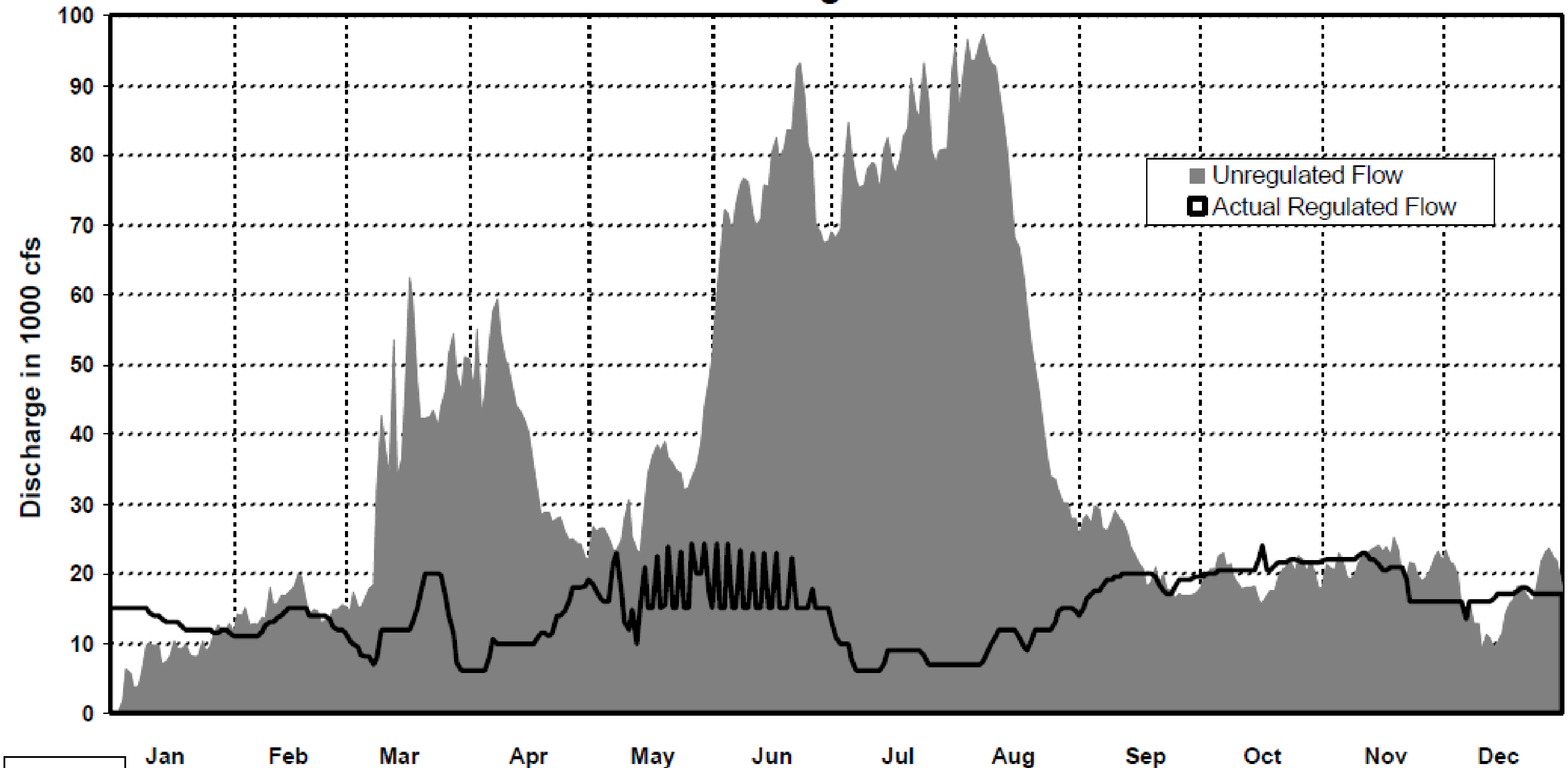
- This has reduced overall intra-annual discharge variability, or conversely, created a more stable and predictable discharge regime



Location Map
Montana
North
Dakota
South
Dakota
Wyoming
Iowa
Nebraska
Kansas
Colorado
Missouri
LEGEND
Missouri River Levee System
Cities
USBR Lakes w/ Flood Control
Other Lakes
COE Lakes
Rivers
States
Bull Hook Dam
Havre
Tiber Dam
Fort Peck Dam
Wolf Point
Williston
Garrison Dam
Great Falls
Pipestem Dam
Jamestown Dam
Jamestown
Dickinson
Bismarck*
Helena*
Canyon Ferry Dam
Heart Butte Dam
Miles City
Bowman Haley Dam
Billings
Aberdeen
Shadehill Dam
Mobridge
Clark Canyon Dam
Oahe Dam
Yellowtail Dam
Yellowstone Lake
Huron
Pierre*
Keyhole Dam
Pactola Dam
Rapid City
Big Bend Dam
Cedar Canyon Dam
Sioux Falls
Fort Randall Dam
Cold Brook Dam
Cottonwood Springs Dam
Boysen Dam
Gavins Point Dam
Casper
Valentine
Sioux City
Glendo Dam
Norfolk
Omaha
Papio Creek (4)
Rathbun Dam
Kingsley Dam
North Platte
Grand Island
Lincoln*
Cheyenne*
Salt Creek (10)
Red Willow Dam
Medicine Creek Dam
Enders Dam
Long Branch Dam
Trenton Dam
Harlan County Dam
Tuttle Creek Dam
St. Joseph
Lovewell Dam
Perry Dam
Smithville Dam
Norton Dam
Kirwin Dam
Denver*
Kelly Road Dam (2)
Bear Creek Dam
Cherry Creek Dam
Chatfield Dam
Glen Elder Dam
Milford Dam
Topeka*
Kansas City
Blue Springs Dam
Longview Dam
Webster Dam
Pomona Dam
Jefferson City*
Bonny Dam
Wilson Dam
Salina
Harry S. Truman Dam
Hillsdale Dam
Bagnell Dam
Cedar Bluff Dam
Kanopolis Dam
Melvern Dam
Pomme De Terre Dam
Stockton Dam
N
W
E
S
100
0
100
200
Miles
U.S. Army Corps of Engineers
Missouri River Basin Civil Works Projects
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

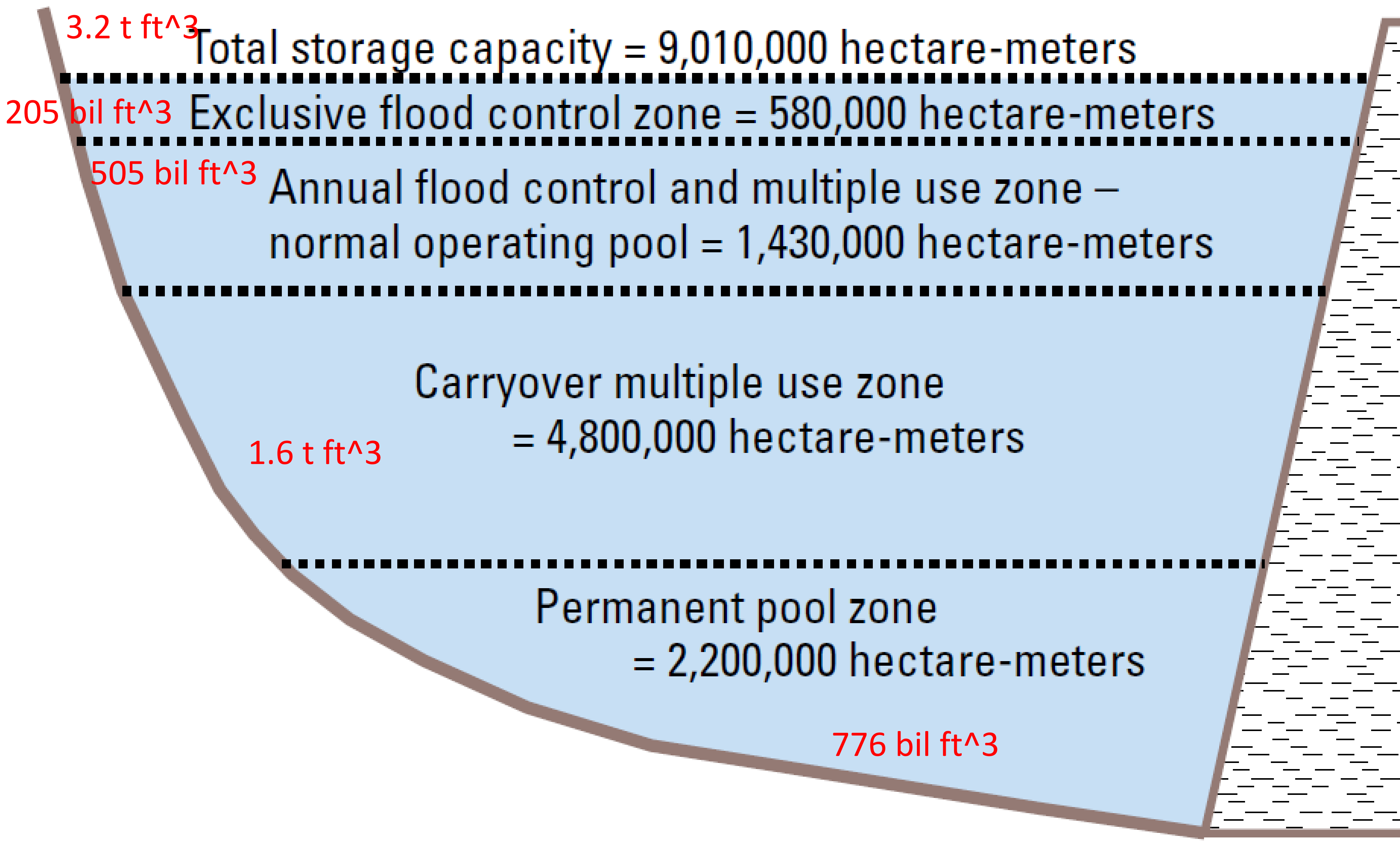
Gavins Point Dam – Regulated vs. Unregulated

1993 Regulation



Missouri River Basin
Gavins Point Dam 1993
Regulation- Regulated vs.
Unregulated

Plate VII-8



3.2 t ft^3
Total storage capacity = 9,010,000 hectare-meters
205 bil ft^3
Exclusive flood control zone = 580,000 hectare-meters
505 bil ft^3
Annual flood control and multiple use zone – normal operating pool = 1,430,000 hectare-meters
Carryover multiple use zone = 4,800,000 hectare-meters
1.6 t ft^3
Permanent pool zone = 2,200,000 hectare-meters
776 bil ft^3

Water Control
Upper Mississippi and Ohio Basins

- Lock and damn systems on the Upper Mississippi and Ohio Rivers are used to raise the stage during low discharge conditions to maintain safe depths for navigation

- Higher discharges result in lower or unchanged stage as structures are overtopped or operated as run of the river during these events

Upper Mississippi Basin Locks and Dams

Ohio River Basin

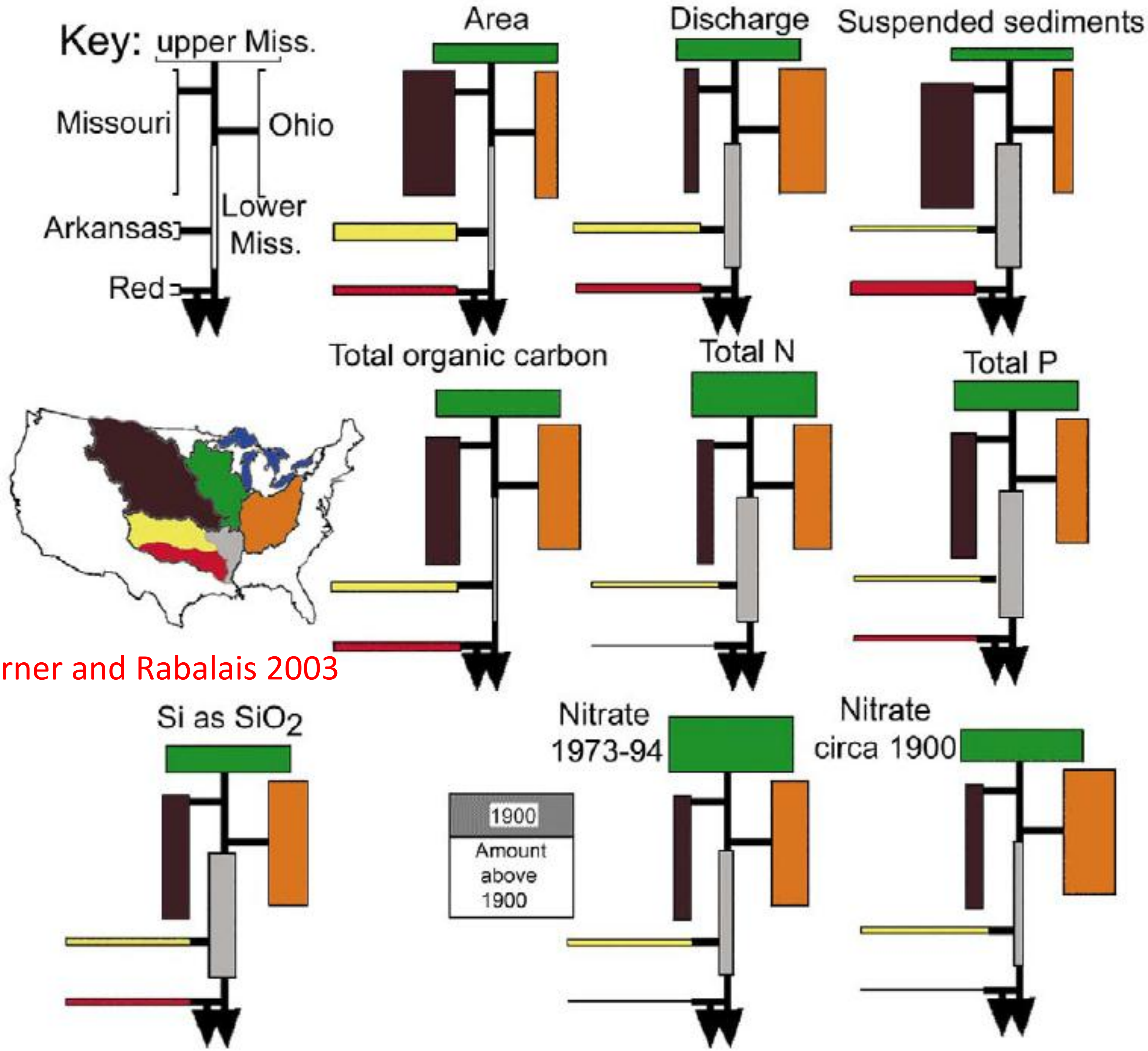
Water Control
Middle and Lower Mississippi River

- No dams have been constructed in the Middle or Lower Mississippi Basins
- Over 5600 km of flood protection levees line the Lower Mississippi effectively cutting it off from its floodplain
- Three flood control structures are integrated into the LMR levee system: Old River Control Complex, Morganza spillway, Bonnet Carre spillway

Suspended Sediment

- In the MRB the primary sources of water and sediment are decoupled
- The Missouri Basin, while contributing only 12-13% of the total annual water flux, is the primary source of suspended sediment, providing an estimated 42% of the total supply
- The Ohio Basin, which supplies the highest water flux, delivers very little sediment
- The Lower Mississippi River Basin boasts the largest sediment yield (flux/catchment area)

Missouri River (L) – Upper Mississippi River (R) confluence

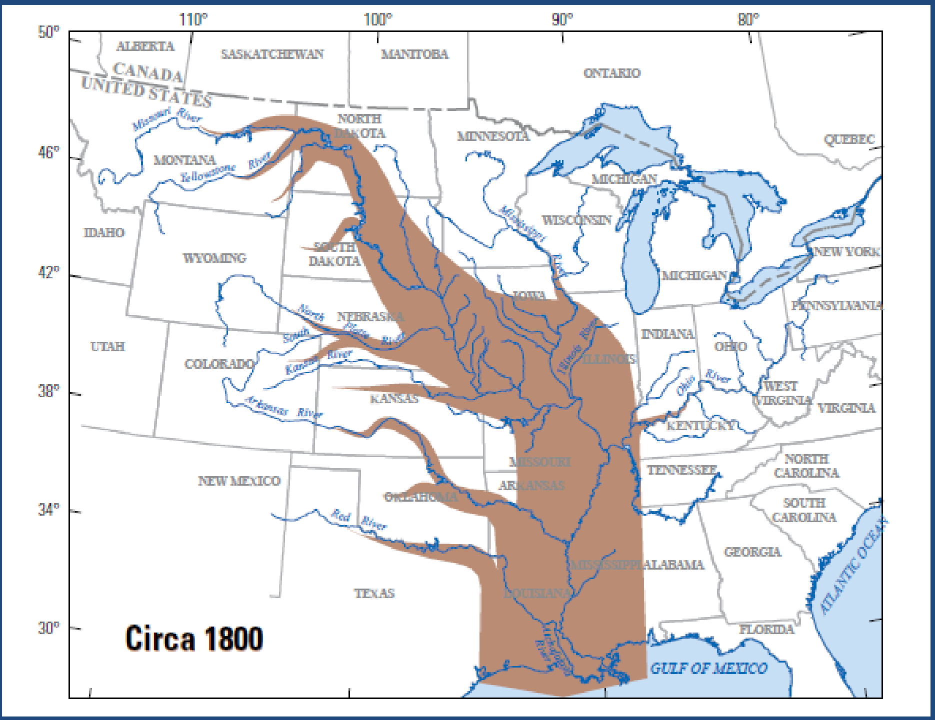


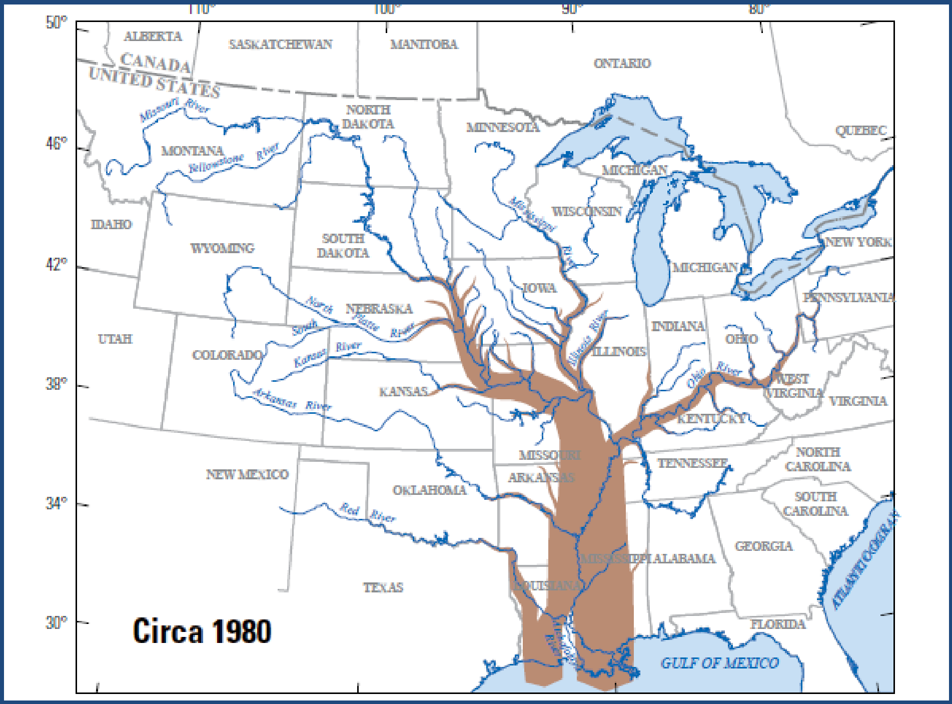
Turner and Rabalais 2003

Suspended Sediment

- Sediment flux from the MRB has been in decline over the last 150 years
- A result of storage in dam reservoirs, improvements in agricultural conservation practices, direct removal from dredging operations, and channel stabilization measures that reduced bank caving

- The decline is mostly in clay and silt size classes, while sand has remained relatively stable


Circa 1800
GULF OF MEXICO
ATLANTIC OCEAN
CANADA
UNITED STATES
Missouri River
Yellowstone River
Mississippi River
North Platte River
South
Kansas River
Arkansas River
Red River
Illinois River
Ohio River


Circa 1980
GULF OF MEXICO
ATLANTIC OCEAN
CANADA
UNITED STATES
Missouri River
Yellowstone River
Mississippi River
North Platte River
South
Kansas River
Arkansas River
Red River
Illinois River
Ohio River

Nutrients

- The Mississippi River has been the dominant source of freshwater, sediment and nutrients to the Northern Gulf of Mexico over geologic time, and has strongly influenced biogeochemical processes, even more so in the past half century

- Input of excess nutrients can result in hypoxic conditions along the Louisiana Shelf

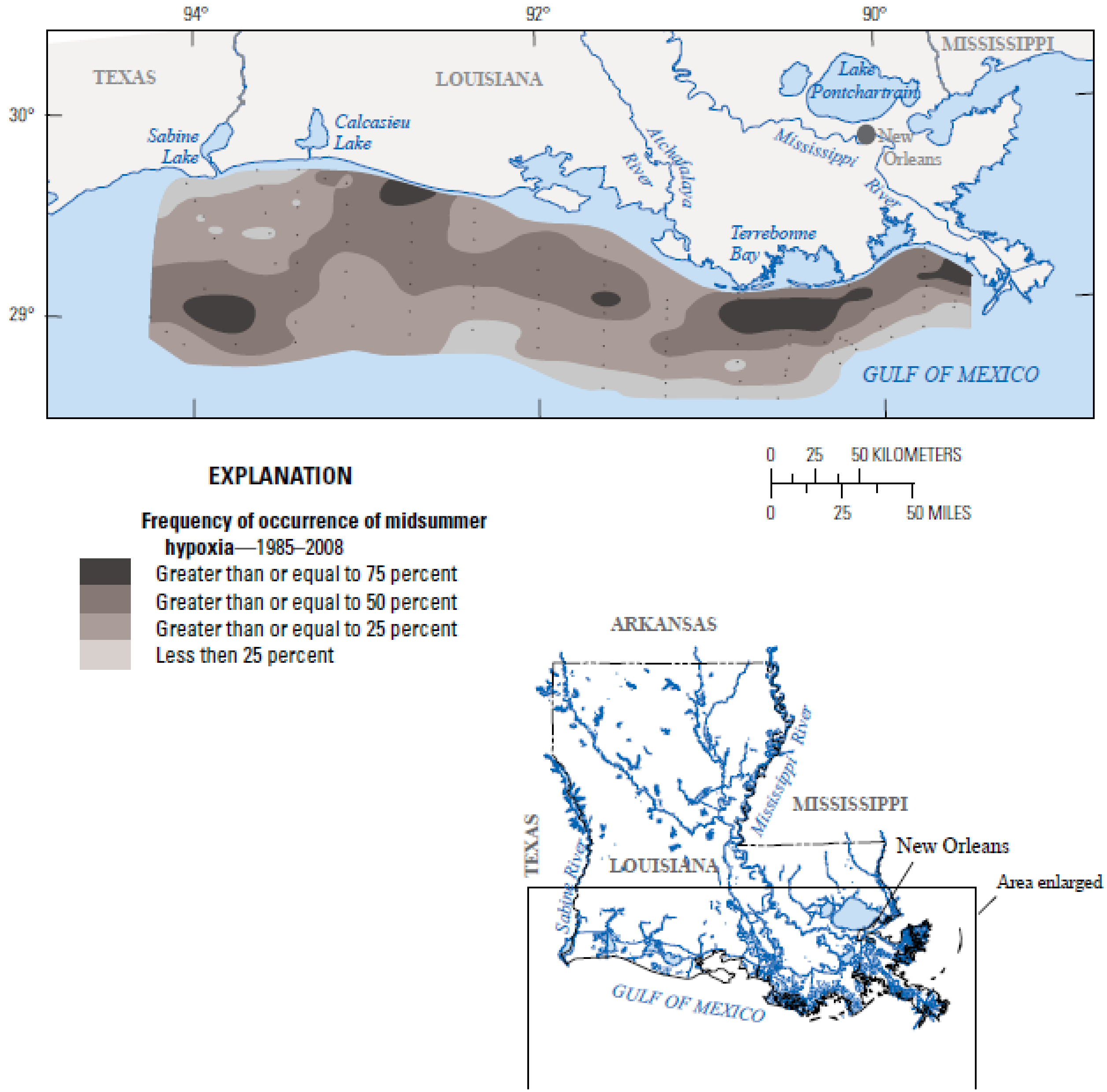
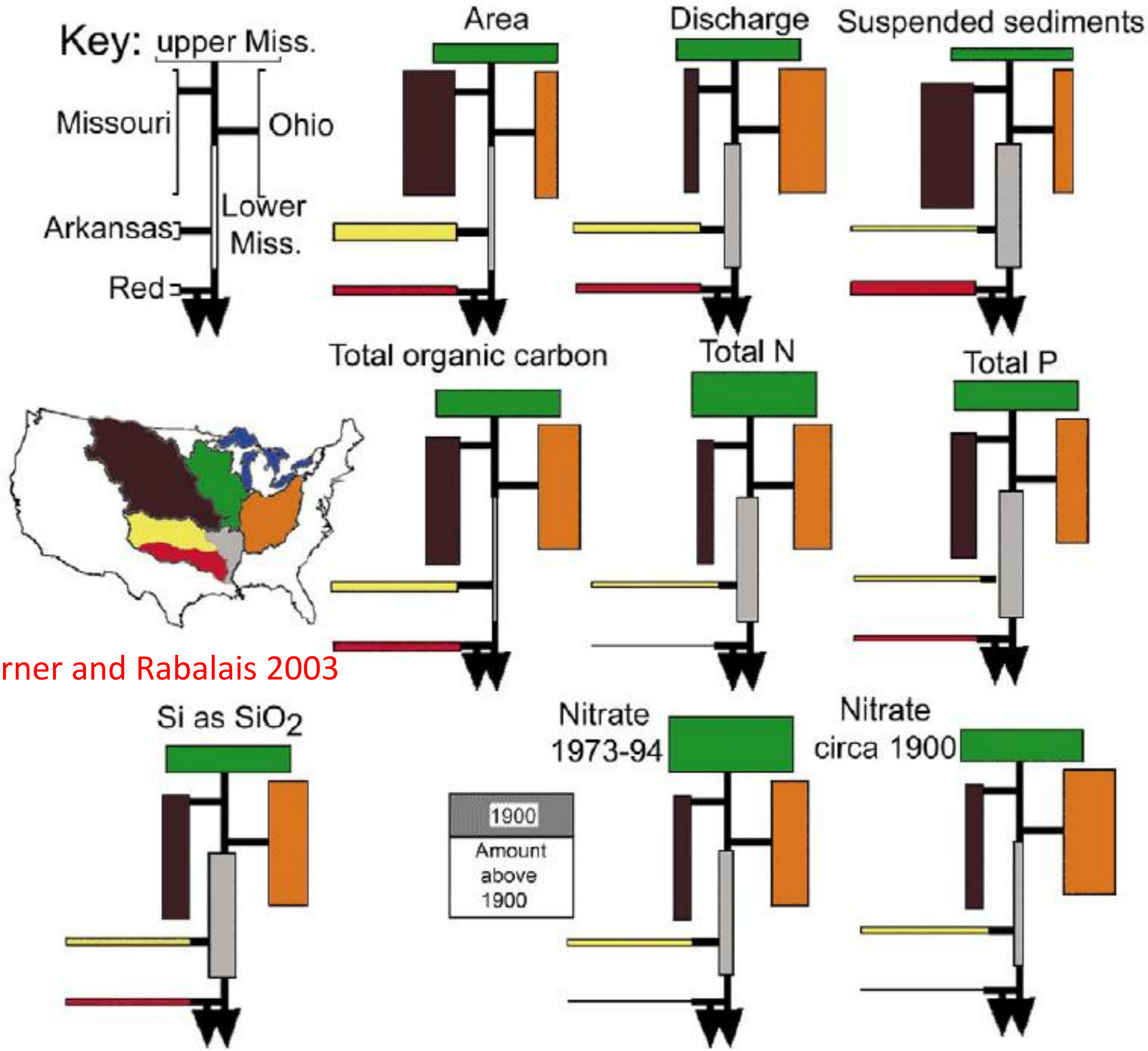


Figure 23. Frequency of occurrence of midsummer hypoxia in the Gulf of Mexico, 1985–2008 (modified from a figure provided courtesy of Nancy Rabalais, Louisiana Universities Marine Consortium).

Nutrient Flux

- The Upper Mississippi watershed provides the highest nitrate and TN load, followed closely by the Ohio watershed
- TP and silicate loads are evenly distributed among the Upper Mississippi, Lower Mississippi, Missouri
- The highest TN and TP yields are from the Lower Mississippi



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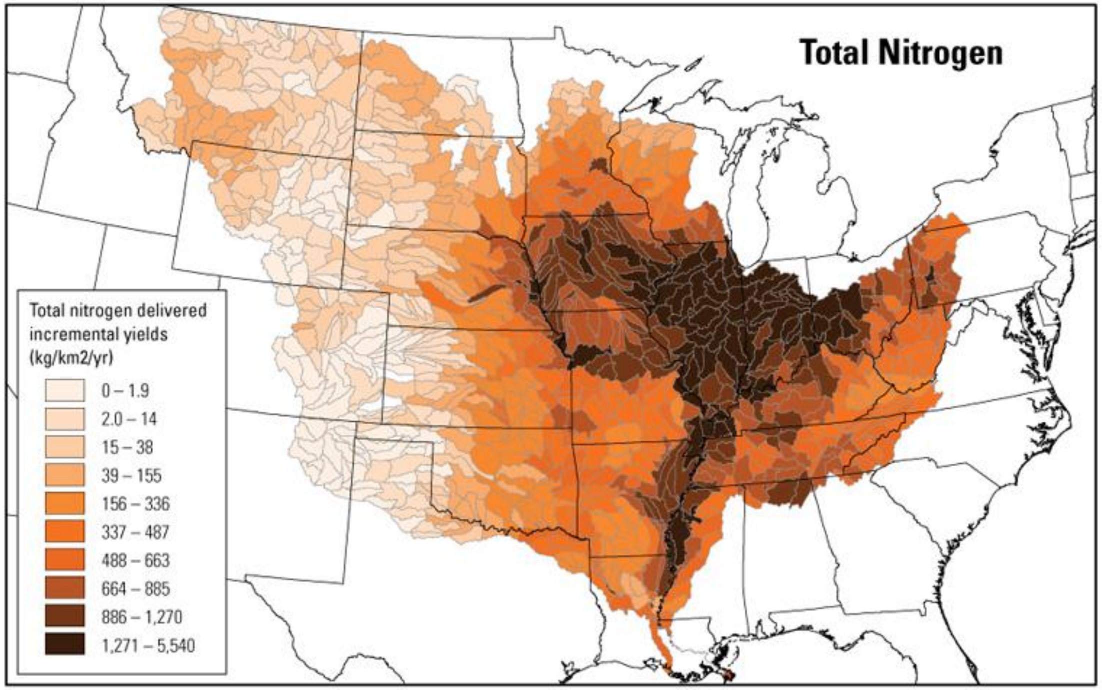

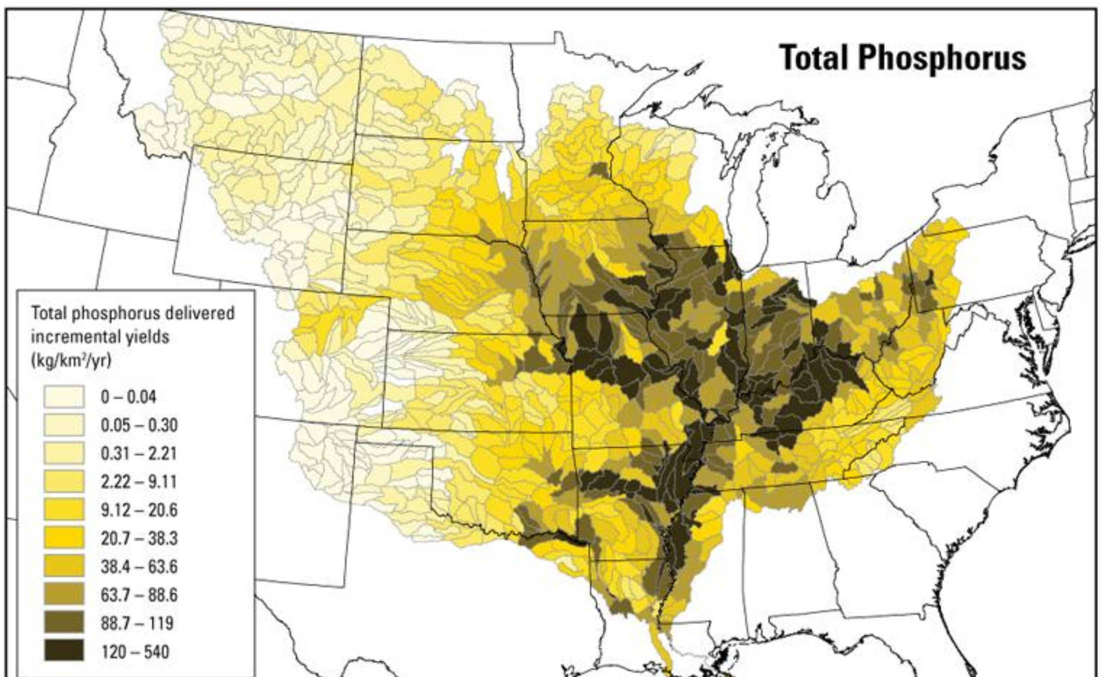

U.S. Geological Survey. For more information: *http://wi.water.usgs.gov/rna/9km30/index.html*

- The flux of water, sediment and nutrients from the sub-basins into the main stem of the Mississippi River is highly complex and only partially understood
- The fluxes have evolved through time in a manner that correlates well with land use and river engineering projects over the past two centuries

- Understanding how these fluxes were influenced in the past should help us predict what will happen in the future as well as answer important questions related to coastal restoration efforts, preserving viable navigation routes and maintaining an acceptable level of flood risk

- We should however, continue to study fluxes of sediment, water and nutrients to maintain situational awareness of trends
- Long term trend analysis can be used to inform the planning of future restoration projects and adaptive management of ongoing navigation, flood control and restoration projects
- Real time monitoring will be beneficial to maximizing the efficiency of land building diversion projects

Questions